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THE GREENLAND EXPEDITION OF 1895.

AFTER an unfortunate delay, the Greenland expedition of 1895, which was to bring Lieutenant Peary back to America, left St. Johns on July 11 in the steamship *Kite*. Instead of heading for Cape Desolation, a more northerly route was chosen, which, had it been held, would have brought us to the coast of Greenland in the vicinity of Frederickshaab. The first stop was to have been at the Frederickshaab glacier, but as the land was approached the fog was so dense and so persistent that it was deemed inadvisable to attempt a landing, and the coast was first seen at a point somewhat further north, in latitude 64° 30′ as nearly as was determined. This was on July 17.

Coastal topography and its interpretation.—The first glimpse of the coast was hardly more than momentary, but it was quite sufficient to reveal the essential features of the coastal topography. Fog shrouded and effectually concealed the lower half of the bold land front, but the upper half consisted of a succession of distinctly serrate peaks, many of them with slopes so steep that it would have been difficult or impossible to scale them. The serration was so pronounced as to be most significant, and seemed clearly to substantiate the general conclusion at which Professor Chamberlin arrived last year, namely, that there were portions of the Greenland coast which have not been glaciated in recent time.

The stretch of coast seen in this latitude was no more than ten or fifteen miles in extent. North of this point the coast was

completely concealed by fog for some miles. When it again appeared, in latitude 65°, as nearly as was determined in passing, it presented a very different aspect. As before, the lower portion of the land, perhaps the lowermost 500 feet, was not seen. The contours of the southernmost portion of this stretch were in striking contrast with those of the region but a few miles further south. Instead of being markedly serrate, the topography was thoroughly subdued, and suggested as strongly as topography can suggest, that the surface had been heavily and recently glaciated. But this was true of the southernmost portion only. In latitude 65° 20′, as nearly as was determined, there was a sudden change in the appearance of the coast. North of this parallel, and extending thence to latitude about 66° 45′ or thereabouts, there succeeded a stretch of territory with serrate front similar to that which characterized the region in latitude 64° 30′. At 66° 45′, or thereabouts, this second stretch of serrate topography gave place to a topography of smooth and flowing contours, indicative of recent glaciation, and corresponding, in all essential features with the topography of the coast just above the 65th parallel. From this point to latitude 69° the coast was seen at intervals only; but wherever seen, it presented the contours which denote vigorous ice-action. The same sort of topography characterizes the coast continuously from latitude 69° to latitude 70°, as was seen in our further progress, so that with the possible exception of short stretches not seen, glaciation would seem to have been continuous along the coast from 66° 45′ to 7 0.

North of this latitude, the coastal topography, while not so markedly serrated as that at 64° 30′, or between 65° 20′ and 66° 45′, was still of such a character as to suggest that if it had been glaciated at all in recent times, the glaciation was not severe. On the whole, judging from topography alone, it seemed more probable that the coast from about latitude 70° north to the end of the Nugsuak peninsula, had not been recently smothered in ice, though it is well possible that the ice-cap may have once extended beyond its present limits, and that isolated glaciers

occupied the valleys leading down to the sea. The northwest end of the peninsula bears the marks of the passage of ice over a considerable part of the coastal front. North of Nugsuak peninsula, and from that point to the south side of Melville Bay, the topography of the coast, so far as seen, indicated general though not universal glaciation. Thus the southwestern end of Svarten Huk peninsula (71° 30′) has a topography denoting the absence of glaciation.

North of the Nugsuak peninsula it was often difficult to distinguish between the topography of the mainland and that of the islands. Ubekyendt Island (lat. 71° 15′), or at any rate much of its west front, has a serrate skyline. North of 72° 30′ also, the topography is not such as to denote continuous glaciation over the outlying islands, even if the mainland was covered down to the water level. It would appear that the comparative phenomena of islands and mainland north and south do not agree—for south of latitude 70° the islands lying near the coast correspond in topography with the mainland opposite.

Except for thirty miles or so east of Cape York, the coast of Melville Bay was not seen. Along that part of the coast which was seen, the ice reaches the sea so generally, that something like three-fourths of the coast line is composed of it. This ice is not the edge of the ice-cap, strictly speaking, but consists rather of a succession of broad glaciers separated from each other by short distances only. In spite of the iciness of the coast it is doubtful if all its islands, even but a few miles from the coast, were ever overtopped by glacier ice.

North of Cape York, the ice-cap is nowhere distant from the coastal margin of the upland; yet there are many considerable stretches where there is no evidence, either in the topography or in the surface formations, that the ice ever reached the sea as a continuous sheet. In many places there is evidence that the edge of the ice-cap approached the coast more closely than now, in relatively recent times, and that its excess of material was discharged in the form of glaciers, some of which occupied valleys now free from them. But even where the ice has been recently extended, there

is evidence of no more than a very moderate increase beyond its present limits, and between the valley glaciers which existed at the time of the greatest extension of which there is record, there often remained peaks or even considerable areas altogether free from moving ice. But there are other areas where the surface affords no evidence that the ice-cap was ever extended much beyond its present limit. Professor Chamberlin has called attention to the existence of a small driftless area[1] on the east side of Bowdoin Bay, reaching almost to the edge of the present ice-cap, basing his determination, not on topography alone, but on the absence of drift, and on the presence of a great body of earthy matter resulting from the decomposition of the underlying rock.

The conclusions reached by Professor Chamberlin last year during his voyage in the *Falcon*, viz: (1) that there are considerable stretches of the west coast of Greenland which have never been glaciated, or at any rate not glaciated within any time so recent as the later epochs of our own glacial period; and (2) that the ice-cap of Greenland—in the vicinity of Inglefield Gulf—was never greatly more extended than at present, or at least that it has not been notably extended within recent times, seem to me to be the only conclusions to which such study as is possible in such a voyage can lead.

This condition of things on the Greenland coast is not without its parallel on the east coast of America (Ellsmere Land, North Devon, Baffin Land, etc.). This coast was seen at intervals from latitude 78° 45′ to latitude 71° 30′. Within this distance there are places where the topography is such as to suggest that the coast has not been glaciated or at least not in recent times. This is true, for example, of some parts of Bylot Island, latitude 73°, and perhaps more conspicuously of a considerable stretch of the mainland coast in the vicinity of Dexterity Harbor, the latitude of which was not exactly determined, but which is not far from 72°. It cannot be asserted, on the basis of present evidence, that there are extensive areas in either of these positions which have altogether escaped the ice,

[1] Bulletin of the Geological Society of America, Vol. VI, p. 818.

but if reliance may be placed on topographic form, it seems clear that in both these places there are considerable stretches of coast over which no ice, except perhaps isolated glaciers, has descended in any recent time. This is the more noteworthy from the fact that the same regions now harbor very considerable glaciers, while the ice-caps which feed them approach very close to the outer edge of the upland. Fully a dozen glaciers, and the ice-cap above which nourishes them, were visible on the northeast side of Bylot Island, while about Dexterity Harbor there are very considerable glaciers, some of them descending nearly to the water level, separated from each other by serrate peaks which do not appear ever to have been over-ridden by ice, though the ice-cap today is no more than two or three miles distant.

In view of the facts already mentioned concerning the topography of the Greenland coast, it seems to be impossible to avoid the conclusion[1] that the Pleistocene ice-sheet of our continent did not have its starting point in Greenland. If reliance may be placed upon coastal topography, the phenomena observed on the American coast would seem to indicate further, that the great center of ice accumulation during the Pleistocene period was not on the most northerly lands on the west side of Baffin Bay. Had this been the case, Bylot Island, and the coast of the mainland in the vicinity of Dexterity Harbor, would hardly have escaped glaciation at the same time that the Labrador coast and its outlying islands were subjected to the action of ice on an extensive scale; and had latitude (at least present latitude) been the determining factor in glaciation, the west coast of Greenland north of latitude 76° would hardly have suffered so slight an extension of its ice as its condition seems to indicate, while more southerly regions were less favored.

It is to be borne in mind that the foregoing conclusion concerning the meager extension of ice-caps of the west coast of North Greenland and the east coast of America, in recent time, is based on general, rather than on detailed observation, and that

[1] Chamberlin, loc. cit., p. 219.

it is possible that the importance of topography in its bearing on this question, has been overrated. But if the conclusion be correct, it will be seen that it is not without bearing on the question of the cause of the glacial period. Of related import is the fact that the conditions for glaciation on the Greenland coast seem to be much better today in latitude 74° to 76°, than in latitude 76° to 79°. It is not merely that there are more and larger glaciers in the former region, descending to lower levels—for all this might be the result of topography—but the snow line itself is 1000 to 1200 feet lower in latitude 76° than in latitude 78°.

Evidence concerning past glaciations, drawn from nature of rock surfaces.—The first stop on the coast of Greenland was at Holstensborg, latitude 67°. The rock in this region is gneiss, which is much more distinctly and regularly bedded than gneissic formations usually are. From a distance, the rock has the appearance of being distinctly stratified, the dip being tolerably constant. So strong was this impression that it was difficult at a distance to avoid the conclusion that the rock was sedimentary. The general dip is to the northward, at an angle of 60° to 75°. On the land, the gneiss is seen to be affected to some extent by dikes of granite, but they are not sufficiently numerous to obscure the general regularity of structure. Its surface has undergone a notable degree of decomposition since glaciation. Striæ were not seen, nor did the rock surface show the polishing which glacial action produces. All these details were gone, although hills having the form of *roches moutonnées* were of common occurrence, and glacial drift was not wanting. This condition of things suggested that the lapse of time since the departure of the ice has been considerable. This is the more significant since it is in striking contrast with the condition of things along some other parts of the coast. It is clear that the cursory examination of the surface of a small area does not afford a safe basis for generalization. Nevertheless it is worthy of note that the amount of change undergone by the surface of the gneiss about Holstensborg since the ice abandoned it, appears to be greater than the average amount undergone by similar forma-

tions in the United States, since the departure of the last ice sheet.

The amount of drift in the vicinity of Holstensborg is slight. From the vessel it appeared as if the larger part of the surface was bare rock, but on the land the proportion of the surface covered by loose material was seen to be somewhat greater. The topography about Holstensborg is such as to suggest that the ice was never very effective in reducing it. It seemed to me probable that some of the higher peaks were nunataks at the time of maximum ice extension, while others of intermediate height were not covered by a great thickness of ice, and did not suffer any considerable modification of form.

The next stop on the coast of the mainland was at Jakobshavn, about 120 miles further north. Here as at Holstensborg, the rock is gneiss, though much less distinctly and regularly bedded. Occasionally it is closely foliated, and the foliations are locally much contorted.

The little peninsula lying north of Jakobshavn was crossed along two lines, and its general features well seen. Its surface everywhere bears the marks of glaciation, and the action of the ice here seems to have been much more intense—so far as topography affords a basis for judgment. Rarely is there better opportunity for observing the topographic effects of glaciation. The relief of the region is about 1400 feet. The surface before glaciation seems to have been affected by an erosion topography, in the early maturity stage of development. In its general westerly movement, the ice smoothed the eastern sides of the hills and ridges, at the same time that it plucked their western sides. The structure of the rock is such as to favor both processes, with ice moving in the direction which it here took, and both processes were therefore carried to an unusual degree. The result was that, standing in almost any valley and looking westward, smooth and relatively even slopes were seen, so characteristic as to leave no doubt as to the agency which produced them, or the intensity of its action, while looking in the opposite direction bold, rough walls of rock, with huge piles of angular bowlders

at their bases, greeted the view. Rarely is the contrast between the lee and stoss sides of hills so clearly marked.

Apart from its topography, the surface of the rock near Jakobshavn was found to be in striking contrast with that at Holstensborg. Instead of being decayed, it was remarkable for its freshness, especially at elevations of a few hundred feet and a few miles inland. For the first few miles from the coast striæ were often seen, but they were also often wanting. Four or five miles inland, and from that point eastward to the limit of the land seen, it was the exception not to find the rock polished, and still retaining the grooves and fine lines due to the graving of the ice in all their pristine freshness, even where its surface has been continuously exposed since the departure of the ice. The surface was such as to give the impression that it had but just been freed from the ice which had polished it.

The bareness of the rock was one of the most striking characteristics of the peninsular surface. It is probably safe to say that half the surface seen in a jaunt of fifty miles is absolutely without soil or loose material of any sort whatsoever; that half of the remainder has a mantle of loose material, averaging less than two feet in depth ; while the remaining fourth has sufficient drift to effectually conceal the rock.

The contrast presented by the rock at Holstensborg and Jakobshavn, both in the matter of topography and freshness of surface, was repeated at other points further north, seeming to indicate that the glaciated surfaces now free from ice along the west shore of Greenland have been free for very unequal periods of time. In some places the surface seems to have been but just abandoned, while in other cases, even where the evidence of severe glaciation is equally conclusive, the surface seems to have been exposed to the influence of weathering for a much longer period of time. This leads to the conclusion that the ice-cap of Greenland did not suffer its greatest extension at all points at the same time. It is quite harmonious with the theory, though in itself does not prove it, that there have been distinct epochs of ice extension (perhaps distinct glacial epochs) during which the

ice-cap moved forward unequally, advancing farther from its present position at one point in one epoch, and at another point in another. Opportunity was wanting to carry observations sufficiently far to place this suggestion on a firm basis of fact.

General disposition of snow and ice. Nowhere on the west coast of Greenland between the latitude where land was first sighted (64° 27′) and 69° was the main ice-cap seen from the Kite, along a course five to fifteen miles off shore. At a few points only, what appeared to be local ice-caps or local snow fields came into view. In one or two places between 66° and 67° there depended from these local snow fields what appeared in the distance to be incipient glaciers. In other places local snow fields were seen of such size that they can hardly fail to give rise to small glaciers, though from our position they were not seen.

At many points along this coast, as seen in July, there were considerable patches of snow, generally occupying ravines, which seemed to be the unmelted remnants of considerable drifts. These occurred at all altitudes, even down to the level of the sea. Many of the patches of snow were of such size and thickness that it was quite certain that they would hold over until the succeeding winter. They were in all cases apparently due to excessive local accumulation by the wind, and do not in any way indicate the altitude of the snowline in these latitudes. The height of the snow line was not determined here, but it is probably not less than 2000 feet, and may be somewhat higher.

North of latitude 68° 30′ the ice-cap appears to approach the coast much more closely than farther south, but even here its edge is so distant and so related to ice-free lands (often islands) in front of it, as not to be generally seen from the open sea. From a point a few miles back of Jakobshavn (lat. 69°), the glacier which bears that name, and the ice-cap beyond, were distinctly seen. Between latitudes 69° and 70° the main ice-cap to the east was now and then seen, either at the head of fjords, or where the coastal topography permitted an unusually unobstructed view to the eastward. North of Prince Island, the end

of the glacier entering the head of Torsukatak fjord was seen—as well as the ice-cap behind it. Further north, during the passage of the Waigat, the local ice-cap of the Nugsuak peninsula was now and then sighted, though it sends no glaciers of importance to the southwest.

With the west coast of the Nugsuak peninsula the east coast of Disco is in striking contrast. On the latter the ice-cap very commonly reaches the edge of the upland, and nourishes numerous small glaciers which descend the slope some hundreds of feet.

Between the north end of the Nugsuak peninsula (lat. 70° 45′) and 74° 30′ the main ice-cap was rarely, if ever, seen. If the published charts be correct, this must have been due to the very considerable number of ice-free islands which lie off the coast, and hide the front of the mainland. That the ice-cap or at least huge glaciers from it reach the coast in very considerable numbers in this region, is demonstrated by the fact that large numbers of bergs take their origin from the coast in these latitudes. The local ice-cap of the Svartenhuk peninsula (lat. 71° 30′) was seen at several points.

The glaciers seen on Disco Island, and on the west coast of Greenland south of Melville Bay, do not depart from the usual type of alpine glacier, so far as general form and relations are concerned. Some of them—as the Jakobshavn glacier—are much larger than the usual alpine type, but they lack the peculiar characteristics which seem to mark the glaciers of the higher latitudes of west Greenland.

The north shore of Melville Bay was not seen except for twenty-five or thirty miles east of Cape York, where the coast line is very largely made up of ice. This ice is mainly in the form of glaciers—as distinct from ice-cap—but they are wide, often confluent, and, where distinct, are frequently separated by no more than trivial areas of land.

It was characteristic of all the glaciers seen along Melville Bay that their gradients were low; that their surfaces were relatively smooth and free from débris; that their centers were

but slightly higher than their sides, that is, that they were but slightly arched in the cross-section; that their vertical fronts were very slight; and that their lateral margins rarely presented vertical sections.

One or two peculiar phenomena of this region merit special mention. In two of the minor indentations on the coast of Melville Bay, the ends of glaciers were seen to be floating. These little bays had not freed themselves from the ice of the preceding winter,—probably not from the ice of many preceding winters. The topographic relations are such as to indicate that the water deepens from the head of the bay outward, and from the lateral margins inward, very gradually. In their advance, the glaciers entering these bays at their heads encounter the bay ice, crowd it, break it more or less, and heap it up in front of themselves. But in the cases referred to, they had not forced it out, and it still constituted a barrier to their advance. The result was that the ends of the glacier were not broken off, or at least not floated away in the form of bergs, as would have been the case in open water. Since the water was shallower near the margins of the bay and deeper in the middle, the lateral margins of the protruding glacier continued to rest on the bottom, while its central portion got beyond its depth and was floated. The deepening of the water from the margins of the bay toward the center appeared to be so gradual, that in neither of the two cases seen did the floating center of the glacier appear to be greatly fractured where it joined the marginal portion which was still resting on the bottom. Similarly the deepening of the waters from the head of the bay out was so gradual that the floating portion of the end was not separated by any notable fault from the ice above which still rested on the bottom. That the central portion was actually floating, however, was shown by the approximate flatness of its surface, by the fact that it was somewhat lower than the marginal parts, in one case as much as thirty feet lower, and by the occasional gaping fissures which exposed the salt water beneath. In both cases the lateral margins of these glaciers, the central portions of

which were floating, carried lateral moraines containing shells worked up from the bay bottom. In one case they were fully thirty feet above sea level. Phenomena of similar import, so far as glacier motion is concerned, were seen at many points, but never in any position except at the immediate edges or ends of glaciers.

In the same general locality there was another interesting phenomenon on some of the islands, and occasionally on the coast of the mainland. Even where the summits of islands were wholly free from snow, several places were seen where their lower slopes had perennial ice-caps reaching down to the water, and even appearing to be thickest at that level. This appeared to be the result primarily of the excessive local accumulation of snow, under the influence of the wind. Lodging against lee slopes, it had reached such thicknesses as to defy the sun. In several places, some of them on islands and some of them on the mainland, the accumulation had gone so far as to give rise to glaciers. That the ice was actually in motion was evinced by its structure, and by the débris which it carried.

Under these circumstances, it was difficult at many points to determine the altitude of the snow line, but on the narrow promontory just back of Cape York a satisfactory determination was made, giving the snow line an elevation of about 1000 feet (aneroid measurement). The ice-cap yielding this result is an isolated one, having an area of no more than five or six square miles. It would seem that the lowness of the snow line here must be the result of local meteorological conditions. There can be little doubt that the snowfall at Cape York is exceedingly heavy, since the small ice-cap referred to has a glacial discharge altogether out of keeping with its area. It feeds two active glaciers, one of which is considerably more than a mile in width, and both of which descend to the level of the sea, discharging small bergs.

North of Melville Bay the snow line is much higher. In the vicinity of Inglefield Gulf it averages fully 2000 feet, and in many places it rises as high as 2200 or 2300 feet. Accompany-

ing the rise in the snow line, though the association may be no more than accidental, the glaciers take on a somewhat different aspect. In general they are narrower, thicker, more arched in cross section, more extensively fractured, and, most striking of all, have, as a rule, vertical sides and ends. Furthermore, their surfaces are much more likely to carry débris along their lateral margins and across their ends, wherever the ends are not more than 150 feet or so thick. These features characterize most of the glaciers seen on the Greenland coast north of latitude 76°. It is true that there are occasional glaciers within this distance which fail to show these characteristics, but they are so rare as to be conspicuous. Thus on the south side of Whale Sound there is a single glacier which has neither vertical sides nor end, although these features are possessed by all the other ice streams on this shore of the Sound. An adequate explanation of this very striking difference in the behavior of the Greenland glaciers north of Cape York and those east and south of that point has not yet been suggested. Such opportunity as was afforded for the detailed study of glaciers was principally within the region where vertical slopes abound.

North of Cape York there is a type of glacier so common as to deserve especial mention. On its seaward margin the upland often terminates abruptly, and from its edge a steep slope descends to the water. The uppermost part of this cliff face, just below the outer edge of the upland is often nearly vertical for a short distance. The junction of the vertical, or nearly vertical, face with the less steep talus slope below, is often the site of great accumulations of snow, drifted thither by the wind blowing from the plateau. These accumulations are not usually continuous for any considerable distance horizontally, but rather are gathered in patches wherever the topography favors lodgment. The patches of snow in these situations have in many cases become so considerable as to give rise to little glaciers. They do not usually descend more than a hundred feet below the snow fields which support them, but their glacier character is unmistakable.

This type of glacier seem to deserve a special name. Since both they and their feeding grounds are on the faces of cliffs, it is proposed to designate them *cliff glaciers*. It sometimes happens that the snow fields which support these tiny glaciers

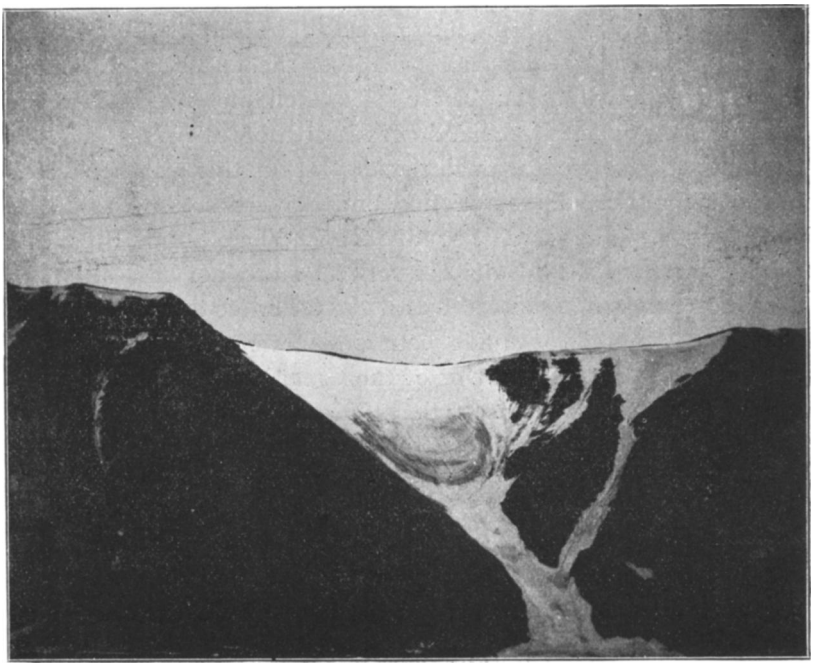

FIG. 1. A cliff glacier on the north side of Herbert Island, a northerly dependence of Murchison Sound. The upper part of the glacier is covered by snow, which also borders it and fills the ravine below. The lack of connection with the ice-cap is shown by the line of rock out-crop above the glacier, the ice-cap lying some distance back.

coalesce laterally along their upper edges. Cliff glaciers were seen at other points, but nowhere else so strikingly developed as north of Cape York. Especially good examples are seen on the north side of Herbert Island and on the east side of McCormick Bay. These glaciers are really one in origin with the low lying glaciers already referred to as originating in huge drifts of snow banked against the lower slopes of islands

and mainland east of Cape York, but they take on a distinctly different form, and the glaciers are much better defined.

The coast west of Baffin Bay has, where seen, a much more wintry aspect than the coast of Greenland in correspond-

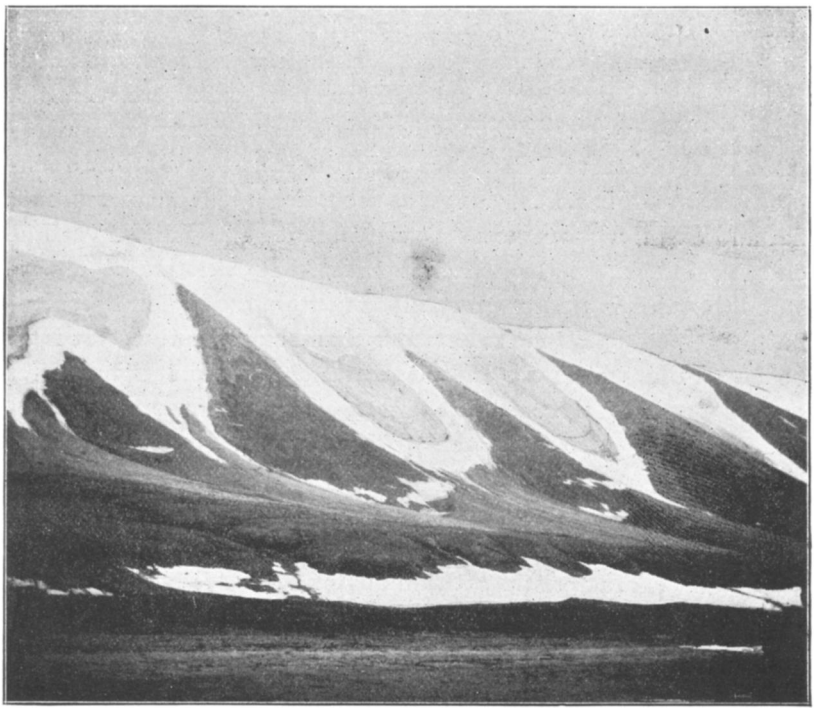

FIG. 2. A series of cliff glaciers on the northeast side of McCormick Bay. The line of rock out-crop at the upper limits of the glaciers is but indistinctly shown in the figure, but is suggested by the dark line.

ing latitudes, Melville Bay alone expected. Where the coast is low, the ice-cap descends to lower levels on the American side of the water than on the Greenland side, leaving a narrower margin of land free from ice. This is in harmony with the fact already noted that the ice-cap comes nearer the coast on the east side of the Island of Disco than on the west side of Nugsuak peninsula opposite. It is also in harmony with the further

fact that the ice-cap of Disco approaches its eastern shore much more closely than its western. In other words the generalization seems to be warranted that the ice is better developed along the eastern borders of land, than along the western.

Not only is the snow line lower on the east coast of America than on the west coast of Greenland, Melville Bay excepted, but the glaciers of the regions present certain contrasts. In and about latitude 78°, the glaciers of the Ellesmere coast were seen at a distance only, but they seemed to possess the general characteristics of those east of Cape York, rather than those of the Greenland coast further north. So far as seen, they are relatively broad, flat and clean, without notable vertical sides and without vertical ends except where they reach the sea. It is not to be understood that this is true of every glacier within the region specified, but it seemed to be the rule rather than the exception. It is to be noted that this is the latitude in which the glaciers opposite, on the coast of Greenland, are notable for their abrupt sides and ends. It is to be noted also that these are the characteristics of the glaciers east of Melville Bay, where the general aspect of the coast, so far as concerns snow and ice, is very similar to that of the American coast.

Similar characteristics mark many of the glaciers about Jones Sound, especially on the south side. Further south, the ends and margins of the glaciers are less abrupt than on the Greenland coast north of Cape York, but distinctly more so than east of Cape York, on the north coast of Melville Bay. In latitude 71° to 73°, there are many glaciers which have vertical sides and ends such as characterize the glaciers of the higher latitudes on the Greenland coast. It is clear, therefore, that the vertical faces of the glaciers are not the result of high latitudes simply. Whatever may prove to be their explanation, it seems to be true that thick glaciers of high gradients are much more likely to possess vertical sides and ends, than thin glaciers of low gradients.

Bergs.—Soon after leaving the harbor of St. Johns occasional icebergs began to show themselves. These proved to be of

somewhat common occurrence, for at the end of the third day thirty-six had been sighted. Since the atmosphere was almost continuously clear, this number may be taken to represent essentially all that were within range of vision from the vessel during the hours of daylight. Although our course was continually bringing us nearer the source of the bergs, only two were seen on the fourth, fifth and sixth days. Their scarcity in this latitude (55° to 62°) was taken to mean that we had passed the eastern limit of the Arctic current, which was bearing them southward. As the coast of Greenland was approached they became again somewhat more common, and by the time Holstensborg was reached not less than 125 had been sighted.

As the coast of Disco was approached from the south, bergs became much more abundant. From the time the coast was sighted until the harbor of Godhavn was reached there was rarely, if ever, a time when as many as fifty could not be seen. Seventy-five were counted in the immediate vicinity of the harbor, and from the land above the settlement, a few hours later, 160 were seen in the little bay to the northeast.

Most of the bergs seen to this point were relatively small, the largest being perhaps not more than 100 feet in height and 200 to 400 feet in length. In most cases they showed that they had been long afloat, and that they had been subjected to considerable changes of position since the beginning of their history, for incisions made by the waves girdled them at all angles. In some cases they were affected by caves and archways, often of remarkable regularity; in other cases their tops were marked by high pinnacles and towers, sometimes having a regularity approaching that of an elaborate architectural design. Without exception they were altogether free from débris, and their colors were the colors of pure ice, varying from white to blue on the one hand, and from white to green on the other. A more perfect or more beautiful gradation of colors could hardly be imagined. More massive bergs were seen at other points, but none more beautiful.

East of Godhavn bergs were abundant continuously to Jakobs-

havn. During the voyage between these points, a distance of about sixty miles, there was hardly a time when less than 100 were in sight, and it is probably quite within the limits of truth to say that 500 were seen between these settlements. So abundant were they that from many points the half of the horizon was concealed by them.

In the Jacobshavn fjord, the upper part of which at the time of our visit (July 23) had not freed itself from the winter's ice,[1] bergs were literally packed. In the outer part of the fjord they were free to move, and were sailing in and out, under the influence of wind and current. But further up the fjord they were imprisoned in the surface ice in such numbers as to suggest that the fjord had not been freed from ice for several years, and that the entire discharge of the huge glacier at the head of the fjord for those years was still fast in the ice.

The bergs in the fjord and near it presented two very distinct types: (1) Those whose surfaces were notably irregular, often a series of ice needles, and (2) those whose surfaces were relatively smooth. The surfaces of the former corresponded with the surface of the glacier above. They were the bergs which had moved out in upright positions. The bergs with smooth surfaces, on the other hand, were those which had capsized at some stage or other of their history, and since they were still imprisoned in the fjord ice, the turning doubtless took place when the bergs separated from the glacier.

The difference in the shape of the upper surfaces was uniformly accompanied by another significant difference. Those with smooth surfaces were always clean, while the upper surfaces of those with irregular tops were always discolored by a thin, discontinuous layer of mud. In this, as well as in their form, the surfaces of the irregular-topped bergs corresponded exactly with the surface of the glacier which gave them birth. It was here apparent that the bergs with clean upper surfaces had shifted their positions in the course of their history, while

[1] Governor Müller, of Jakobshavn, is authority for the statement that the fjord is not usually freed from ice oftener than once in four or five years.

those with dirty surfaces were still right side up. The conclusion that bergs with clean surfaces have been tilted or capsized in the course of their history was first reached at Jakobshavn, but it proved to be of general application. The ends of all glaciers seen had their surfaces covered with a sufficient amount of débris, mainly wind-blown dust, to give them a distinctly grayish appearance. In consequence, every berg originating from them, if it set sail without capsizing, must have a discolored surface. That many bergs do begin their history right side up — that is, with the parent glacier surface up — is shown by the fact that in the immediate vicinity of the calving glaciers the upper surfaces of many of the bergs are discolored.

In no case did the vertical faces or upper surfaces of the bergs about Jacobshavn show bowlders or detritus of any sort. This was in perfect harmony with the phenomena exhibited by the end of the glacier which had given origin to them, for neither its vertical front nor its upper surface showed a single stone, large or small, nor any trace of finer material. This in itself seems to be sufficient proof that the small amount of fine débris upon the upper surface had reached its position at the hands of the wind.

The bergs calved by the Jakobshavn glacier were 100 to 200 feet above water, and the vertical end-face of the glacier was of corresponding height. It is clear, therefore, that the thickness of the glacier at its end is very great. That its lower layers, and consequently the bottoms of the bergs at the beginning of their history were charged with débris, can hardly be doubted.

Above Jakobshavn, bergs continued to be plentiful through the north part of Disco Bay, though perhaps less abundant than opposite the Jakobshavn fjord. To the south entrance of the Waigat there was rarely a position where as many as fifty might not be sighted, and their average size was greater than at any point further south. While they did not often exceed eighty or one hundred feet in height, they were often 1000 feet or so in horizontal extent. Here for the first time occasional bergs were seen in which certain well-defined layers of ice, containing

more or less earthy débris, stood out distinctly between the layers of cleaner ice on either hand. This was seen only in bergs which had been tilted, so that the originally horizontal layers had become highly inclined. The débris-laden layers were apparently layers which were near the bottom of the parent glacier and near the bottom of the berg at the beginning of its history.

A considerable procession of bergs was seen coming out of the fjord north of Prince Island, some of them being very massive. In this region an occasional berg was seen so completely covered with débris as to be essentially black. Such bergs were all very low, none of them being more than ten or fifteen feet in height. As subsequent observations indicated, they must have come from glaciers, the ends of which, as they reached the sea, were very thin; that is, glaciers, the upper surfaces of which were very near the lower. They therefore do not violate the general rule that the débris of the glaciers is not far above their bases. Glaciers with thin ends and edges, and such only, have abundant débris, apart from occasional medial moraines, on their upper surfaces.

In the Waigat, and for a considerable distance north of it, the bergs were, on the whole, considerably flatter than those further south, rarely standing more than fifty feet out of water. From thirty to fifty were generally in sight until the entrance to Umanak fjord was approached. Here a noble fleet of them, more than 100 by actual count, was seen sailing out from the narrow bay. Some of them were so large areally that the water produced by the melting of their surfaces gathered into streams of considerable proportions. From the upper edge of a single berg in this locality, three such streams were seen to be falling, each of which carried a very considerable body of water. The bergs were remarkably regular, such serration as characterized the bergs coming from the Jakobshavn glacier being wholly wanting. Most of them had never been overturned or even tilted; yet they were measurably clean, nothing more than a little dust being in any case visible upon their surfaces. Considerable processions of bergs seemed to be coming out of the waters north

of Ubekyendt Island, and until the Svartenhuk Peninsula was reached, they were constantly in sight in great numbers.

Through Melville Bay, bergs were rarely seen. This may have been due partly to the fact that much of this stretch was passed in a foggy atmosphere, and vision was correspondingly limited. About Cape York, bergs were found in extraordinary numbers a little later, as also for a considerable distance east of this point. So abundant were they at Cape York toward the end of August that from a single position 1200 feet above the settlement just east of the Cape, about 700 were counted. Many of these were of great height, and of great areal extent as well. On the whole, this was much the noblest assemblage of bergs seen. They were not more remarkable for their size than for their freedom from débris, and for the extent to which they had been sculptured by the waves. Though without the marked serration of the bergs at some other points, their forms were often exceedingly fantastic. Here was seen the most unique berg observed at any point. From the bluff above Cape York its surface was seen to be marked by a huge, steep-sided depression, circular in outline. Its depth was considerable, its bottom appearing to be at least as low as the level of the sea. It was filled with water, the level of which appeared to correspond with that of the water in which the berg floated. The color of the water was such as to suggest that it was salt, and therefore that the depression extended quite through the berg from top to bottom. This was not, however, demonstrated. The origin of such a depression is not altogether clear, but it was probably developed while the berg was in another position. Other bergs about the Cape were notable for their huge amphitheatral reëntrants, sometimes 200 or 300 feet deep.

The bergs at Cape York were in process of rapid dissolution. At the time of our visit, the weather chanced to be sunny and warm, and the bergs appeared to have been afloat long enough for the ice to have become rotten. There was no period of more than a few minutes duration at any time during the fifty odd hours spent in this vicinity when reports due to their disruption

were not heard. These reports resembled thunder much more closely than any other familiar sound, and, awakened by them in the night, the resident of lower latitudes could hardly fail to think, at the first moment, that it was a sharp clap of thunder that had roused him, and that a violent thunderstorm was raging.

Bergs occurred in considerable numbers in Wolstensholme Sound, in the upper part of Whale Sound, in Murchison Sound, and in Inglefield Gulf and its dependencies. North of Murchison Sound and between that point and Cape Sabine, latitude 78° 45′, bergs were nowhere abundant. There was probably no time during our passage through these waters when as many as two or three were not in sight, nor were there often times when more than a dozen could be seen. They were of even less frequent occurrence between Cape York and Coburg Island. In Jones Sound they were present in moderate numbers, while along the American coast south of that point to latitude 71° 30′ they were rare. There were frequently considerable intervals where not one was in sight, while at other points considerable clusters of them came into view.

Between Disco and the Labrador coast, on the return voyage, bergs were never abundant as compared with those in many other stituations, but they were almost never wanting. An approximate idea of their abundance in these waters may be obtained by the general statement that there was rarely a time when less than half a dozen or more than forty could be seen. Their numbers diminished with increasing distance to the south, and they practically disappeared before the coast of Newfoundland was reached. On the whole, the impression gained was that a very large amount of ice is discharged from the land in the form of bergs.

The highest berg seen was probably not more than 200 feet in height. The greatest areal extent of any berg seen was probably not more than one-third of a square mile, the maximum length being, perhaps, about a mile. These figures, it is to be understood, are the results of estimate, not measurement.

The almost uniform freedom of the bergs from débris is in

itself a sufficient refutation of the idea that glacier ice is in general charged with débris. Extensive observation makes it certain that so far as west Greenland is concerned, only the lower portion of the ice of a thick glacier contains débris. There is little débris above the lowermost 100 or 150 feet of ice. As bergs are calved from massive glaciers, their lower portions doubtless carry a considerable quantity of material, but this appears to be dropped before they have proceeded great distances, for the bergs which are overturned or upturned rarely show any trace of it. On the other hand where a thin glacier reaches the sea, its bottom is not far from its top, the former being brought down nearly to the latter by melting, and the whole mass may be full of débris, without interfering with the general truth of the statement that débris does not rise any considerable distance above the bottom of the ice. From such glaciers only small bergs arise, and these may be well charged with rock rubbish from bottom to top. In spite of the possibilities in this line, and in spite of the fact that bergs from massive glaciers often capsize so as to bring their basal parts into view, rock débris on or in the Arctic bergs is yet so scarce that it would probably be within the limits of truth to say that not one berg in five hundred of those seen carried detritus of any sort, except dust which had been blown upon the glacier before the berg was detached.

Comparing the phenomena of 1895 with those of 1894, as seen by Professor Chamberlin, it appears that bergs were very much more abundant this year than last. This is in keeping with the fact that the warm season seems to have come on somewhat earlier than usual in 1895, at least in central Greenland, and that certain bays and fjords cleared themselves of ice somewhat earlier than is their wont, getting their bergs well to sea at an unusually early date, while other bays which often remain covered with ice for many years in succession, thereby holding all bergs discharged into them, this year cleared themselves, sending all their many bergs to sea.

Floe ice.—It is worthy of especial note that no trace of floe

ice was seen along the coast of south Greenland. Approaching the land further north than expeditions have commonly done, it would not have been strange had we encountered less than the accustomed amount of ice, but we neared the coast sufficiently far to the south to have encountered at least the northern portion of the stream of ice which, coming down the east coast, usually rounds the point of Greenland, and passes northward along the west coast as far as Holstensborg. The fact that no ice was seen, where a wide belt of it usually occurs in corresponding seasons, seems to mean either that it disappeared much earlier in 1895 than usual, or that it was much less abundant, or both. From various facts which came to our knowledge, it seems that the former was certainly true, perhaps also the latter.

The first floe ice was encountered in the latitude of Upernivik, a little below 73°. The small pack of ice here seen, made up in considerable part of disrupted bergs, extended out a considerable distance from the coast. The floe ice of the pack was thin, and the pans were considerably tilted. A considerable number of small bergs were held in it.

In passing Melville Bay during the last days of July, but a small amount of ice was seen. Occasional pans a few yards, or in some cases a few hundred yards in diameter, were encountered, but they were rarely so abundant as to occasion any considerable deviation from a direct course. The pans were low, usually standing no more than a foot or two out of water, and were much perforated, indicating that they were near the last stage of dissolution. East of Cape York, toward the end of August, a considerable amount of floating ice was found, but it was nowhere sufficiently close to prevent navigation. In Whale and Murchison Sounds, and in the outer portion of Inglefield Gulf, ice was so abundant as to seriously interfere with navigation during all the first half of August. North of Murchison Sound, in the northern part of Baffin Bay, there was little ice, and Smith Sound was relatively free from it, except its northern end. Here, at the entrance to Kane Basin, the ice was plentiful.

On the American coast, floe ice was somewhat abundant in

Jones Sound, increasingly so with increasing distance to the west. Forty miles or so from the entrance, navigation became difficult. South of Jones Sound, little ice was encountered until latitude 72° 30′ was reached. Here it became more plentiful, and further south, in latitude 71° or thereabouts, a very extensive pack was encountered, the east-west extent of which could have been little less than 200 miles. Its extension southward was not determined, but southwest of Disco, in latitude 66° 30′, the east edge of a considerable pack was touched, which may have been continuous northward with that which had been encountered in latitude 71°. If so, the north-south diameter of the pack must have been as much as 300 miles.

Evidences concerning recent changes of level. On the whole, the evidence gathered concerning recent changes of level along the northern coasts is rather meager. This is not to be interpreted as meaning that such evidence is necessarily wanting, but merely that it is not usually so obtrusive as to be detected upon cursory inspection. Even the absence of topographic evidences of changes of level would not necessarily mean that such changes have not taken place. The study of the coastal lands here, as elsewhere, led to the conviction that a region may be submerged and reëlevated, without preserving very distinct topographic evidence of the change.

The topography of most of the land front seen, both on Greenland and on the continent, is without any notable horizontal element; that is, terraces, beaches, etc., if present at all, are generally, though not always, so inconspicuous that they were not detected in passing, even when the course was so close to the coast as to afford excellent opportunity for studying the details of its topography.

At Jakobshavn striæ were seen on the gneiss down virtually to the level of the water. Their presence at this low level is perhaps not especially significant so far as changes of level are concerned. If the land has risen since they were formed, the shore line probably did not remain long at the level at which they occur. Their presence at the sea level, and at all higher

altitudes, would seem to mean that if the land has risen since glaciation, it rose rapidly. Nothing was seen about Jakobshavn which was taken to mean, necessarily, a recent uplift of the land, though features were seen which would be consistent with such movement.

Between Jakobshavn and Cape York but a single stop was made, but the coast (perhaps only islands) was seen almost continuously from the former place to latitude 74°. Nothing was seen in the topography at any place between these points to indicate recent changes of level, if the fjords be not considered such evidence. It should be stated, however, that the course of the *Kite* was frequently so far from shore, that minor, or even reasonably distinct, topographic evidences of rise might have escaped notice. Further north, positive evidences of recent rise were seen at various points. Thus there are well defined terraces on the east side of Saunders Island in latitude about 76° 35′. The elevation of these terraces was not determined as no landing was made on the island, but the highest may have been something like 100 feet above the water. Again, in Olrik's Bay, a dependence of Whale Sound, just above the 77th parallel, there are considerable deposits of sand containing abundant marine shells of species still living along the shore, at elevations ranging up to 150 feet at least. These sands are conclusive proof of recent elevation of the coast in this region by an amount equal to the height of the sands themselves, yet topographic evidence of this change of level is nowhere conspicuous along any part of the bay seen, and at many places is altogether wanting. The end of a large glacier descending toward the bay from the elevated lands on the south, rests on and conceals the upper part of these shell-bearing sands.

Nowhere else in Whale Sound or Inglefield Gulf was anything seen which seemed to necessitate the conclusion that the land has recently risen or sunk. Near the west end of Herbert Island, on the south side of Murchison Sound, there is a terrace which very likely signifies recent elevation. It is less well defined than that of Saunders Island, and its altitude is comparable. Elsewhere about the island distinct terraces are wanting.

The most conspicuous terraces seen were in the vicinity of Littleton Island, in latitude about 78° 30′. Here on the mainland coast, there is a notable series of terraces, at least three in number, which seemed clearly to have been fashioned by the waves. Opportunity was not afforded for their measurement, but the highest could hardly have been less than 300 or 400 feet.

It will be seen that the points where positive evidence of recent rise was found are distributed in latitude between 76° 35′ and 78° 30′, a stretch of something like 120 miles; but within this distance there seemed to be complete absence of evidence of recent submergence at most points. If one may trust topographic evidence, and such evidence as interrupted study on the shores themselves furnished, it would be as rational to conclude that the coast through this region has risen at certain points, while others have remained stationary or have subsided, as to conclude that it has risen at all points because it has risen at some. It is not believed, however, that anything less than an uninterrupted study of the coast through long stretches will afford positive evidence concerning the point in question, and the absence of topographic evidence of recent elevation at many points is therefore not interpreted as necessarily meaning absence of recent elevation at those points.

On the American coast a somewhat similar condition of things exists. On Smith Island, in Jones Sound, there is positive evidence of recent elevation to the extent of fifty feet, and less satisfactory evidence of a much more considerable rise. South of Jones Sound a horizontal element in the coastal front is often wanting, though sometimes present. It was somewhat conspicuous on Philpot Island, latitude 75°, though no landing was made at this point, and the significance of the horizontal element was therefore not determined. Suggestions of terraces were also observed at some points on Bylot Island. At Dexterity Harbor, about 72°, opportunity was afforded for more careful examination of the evidence bearing on this question, and here there was positive evidence of recent elevation to the extent of something like 480 feet, aneroid measurement. Beaches and flats of limited

extent succeeded each other at frequent intervals up to this level. Along the line of ascent, seven tolerably well defined beach lines were noted, while on the line of descent, but a short distance from the former, two more were counted. From a short distance off shore these successive stages were altogether unseen, although the whole of the considerable stretch of territory below 500 feet had the general aspect of a marine plain. It is probable that detailed examination of the coast at other points would give specific information, which was not detected from the *Kite*, concerning the stages of rise

In conclusion it may be stated that while recent changes of level have certainly taken place at some points, and that they locally amount to several hundred feet, observations were too disconnected and too meager to make out the general system according to which they took place, or the general principles governing them.

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